

APPLICATION FOR UNITED STATES PATENT

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MICROMINIATURE ZOOM SYSTEM FOR DIGITAL CAMERA

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Background of the Invention

Mobile communications devices are becoming more compact while their functions and features are ever expanding. As a next step in this process of expanding 5 applications, a digital camera may be installed. This requires a new cycle of development with respect to the digital camera in order to package the necessary functions within the compact profile of the mobile communications device. In order to miniaturize the camera 10 for such use, the zoom feature is often eliminated or substantially reduced in functionality. This is because the apparatus needed to move the lens in a traditional zoom mechanism is cumbersome. The development is facilitated by the introduction of digital, semi- 15 conductor, imaging sensors, such as CCD and C-MOS sensor arrays.

In addition a new class of micro-miniature components have become available that provide the 20 functionality of both electrical and mechanical components. These components are fabricated in a process similar to the manufacture of integrated circuit chips, namely the surface treatment of silicon wafers. These mechanisms can provide the function of sensors 25 (resonators), actuators, transducers, motors, and gears to high tolerances. By micro-machining silicon wafers layered on a substrate, the components, of the so called micro-electromechanical system (MEMS), are constructed on a thin substrate. A description of MEMS components is 30 contained in Philosophical Transactions of the Royal Society: Physical Sciences and Engineering, Series A, Issue no. 1703, December 15, 1995, pp. 355-366, which is incorporated herein by reference.

It is a purpose of this invention to provide an autofocus and zoom system for a compact electronic device. A further purpose of this invention is to provide these functions by using a sensor array, such as 5 a C-MOS sensor array, and a lens actuation mechanism suitable for fabrication on a silicon wafer. It is a further purpose of this invention to utilize the advantages of micro-electromechanical system (MEMS) manufacturing techniques to obtain these goals.

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Summary of the Invention

A miniaturized digital camera is constructed for use with a mobile communication device or other compact appliance. The optical system of the camera consists of 15 a small lens system having the traditional components of a primary lens, a variator lens, and a compensator lens. The lens system transmits the image received from an external source to a sensor array. The sensor array is constructed on a substrate using silicon wafer 20 fabrication techniques and is positioned to receive the image from the lens system. The array is operatively associated with a micro-electro mechanical component for movement between at least two positions by actuation of the MEMS component. Both the array and the MEMS 25 component are constructed on the same substrate utilizing similar techniques to create an extremely small fully functional imaging system for use with the lens system. Actuation of the MEMS component, will move the sensor array relative to the lens system. Such actuation of 30 the MEMS component, can be accomplished in response to, for example, the sensed distance of the lens system from the subject of the image. In this manner an autofocus function can be accomplished. The movement of the sensor is combined with a coordinated movement of the variator

and/or compensator lenses to provide a zoom function. To facilitate this coordinated movement one or both of these lens can be mounted for movement on the MEMS component in operative association with the sensor array. Since the 5 position of the sensor array can be varied the movement of the lens-system/lenses could in some cases be reduced. With a suitable lens design and by moving the sensor array itself, it could e.g. be possible to reduce or completely omit the movement of one of the lenses, e.g. 10 the compensator. In this manner a variety of configurations can be accomplished to provide the zoom and autofocus functions in a miniaturized version of the traditional system.

15 **Description of the Drawing**

The subject invention is described in more detail below with reference to the drawing in which:

Figure 1a is a schematic illustration of a 20 traditional lens system with a fixed sensor array;

Figure 1b is a schematic illustration of a lens system in which the sensor array is mounted for movement;

25 Figure 2 is a schematic illustration of the sensor array of this invention fabricated with the MEMS component for multiple positions;

Figure 3 is a schematic illustration of the sensor 30 array and lens system fabricated and mounted for coordinated movement on the MEMS component; and

Figures 4a, 4b, and 4c are schematic illustrations of a traditional lens system, showing the various relative positions of the lenses.

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Detailed Description of the Invention

A typical optical lens system 1 for a camera having autofocus and zoom capability is depicted schematically 10 in figures 4a - 4c. It generally will consist of a primary lens 2, a variator lens 3, and a compensator lens 4 which are operatively associated to project a focused image on image plane 5. As shown, the lens has three "principal" positions, i.e., wide angle, middle and 15 telephoto. The zoom function can be a smooth movement between the two end positions (wide and tele) and do not necessarily have to be a stepwise action with only three options. These variations in function are provided by moving the variator and compensator lens, 3 and 4 respectively, as shown. Lens system 1 is used in a 20 digital camera 6, as shown in figure 1, in which the lens system 1 is secured within a housing (not shown) to project an image on an image sensor 7 positioned at the image plane 5 of the camera 6. The assembly of lens are 25 adjusted, as shown in figures 4a - 4c to obtain autofocus and zoom functions.

In accordance with this invention, the mechanical movement of the lens system 1 is constructed through the 30 use of advanced micro-machining techniques. Through such techniques, a semi-conductor image sensor can be combined with a lens system in a unique manner to obtain substantially the same functions as described above. The resulting image generating system can be exceedingly

small and therefore can be conveniently packaged within the confines of a mobile communications device, such as a cellular telephone. As shown in figure 1b, a semi-conductor image sensor 9 is supported for movement by a 5 micro-machined actuator assembly 10 in operative association with lens system 8 and positioned within the housing 11 of a digital camera or mobile communication device.

10 The actuating assembly 10 of the digital camera is shown in more detail in figure 2. In the actuating assembly 10, an image sensor 13 is constructed with its associated electronics on a semi-conductor chip 14. Terminal 15 provides the sensor 13 with appropriate 15 electrical contact to power the sensor 13. A micro-electrical mechanical system (MEMS) 16 is formed on substrate 17 to support the sensor 13. MEMS 16 may take many different forms depending on the function of the camera and the fabricating technique used. For the 20 purpose of illustration, a series of electrostatic resonators 18 are schematically shown. Electrostatic resonator 18 is an example of a linear actuator which can be used as a precise positioner, among other things. Actuator 18 consists of a pair of bases 19 which are 25 fixed to the substrate 17 and moveable supports 20. Supports 20 are connected to bases 19 by means of electrostatic fingers 21. Sensor chip 13 is connected to movable supports 20 by a further pair of electrostatic fingers 22. The moveable supports 20 and the sensor chip 30 13 can be moved by applying a voltage between the moveable structure and its immediately adjacent supporting structure. For this purpose contacts 23 are provided on moveable support 20 and contacts 24 are provided on bases 19. The actuating assembly 10, as

shown in figure 2, provides a two position motion utilizing the movement of moveable supports 20 on their associated bases 19 and the movement of the sensor 13 on supports 20. For further information, see the article 5 entitled "What is MEMS" at <http://www.mems.engr.wisc.edu>.

Since, as shown in figure 2, the sensor 13 is shown mounted on the substrate 17, this particular embodiment could be adapted to provide autofocus, if used within a 10 conventional lens system. If however the sensor 13 was mounted on the substrate 17 (see phantom lines 12) and replaced by a lens mounted on the illustrated support assembly, a zoom mechanism could be provided.

15 In the alternate embodiment shown in figure 3, a MEMS support assembly is shown which may be adapted to provide both autofocus and zoom functions. In this embodiment, a lens 24 is mounted on a three position (or smoothly variable) MEMS support assembly 25 to the 20 substrate 26 through base element 27. An image sensor 28 is also mounted for independent motion on a two position MEMS support 29. This system may be adapted to provide both an autofocus and a zoom capability.

25 The image sensor used herein is a semiconductor C-MOS sensor array constructed using standard silicon processing techniques which are compatible with the MEMS fabrication process. In addition appropriate electronic or manual systems would be connected to initiate 30 operation of the functions provided. Ideally the sensor array is constructed on a chip with imbedded control circuitry including sensors, memory, and other functions.

The MEMS technique used may be surface micro-machining. This method is an additive fabrication technique which involves the building of the device on top of the supporting substrate. The substrate would be 5 constructed with the necessary imbedded control circuitry, for example as an application specific semiconductor integrated circuit. In this way the digital image sensor and the micro-electromechanical zoom are manufactured on the same chip using silicon based 10 microelectronics for the sensor and micromachining technology for the micro-electromechanical support.

In this manner a micro-miniature digital camera having a variety of basic functions can be fabricated in 15 a cost effective manner for use with a mobile communication device.